ISSN: 1519-7859 https://doi.org/10.4322/rae.v15e202105.en

ASSOCIAÇÃO BRASILEIRA DE ERGONOMIA

Revista Ação Ergonômica

www.abergo.org.br

EVALUATION OF THERMAL STRESS IN VEHICLES USED IN RADIO PATROLLING SERVICES DURING THE SUMMER OPERATION IN THE MUNICIPALITIES OF CARAGUATATUBA AND SANTOS/SP

Ana Carolina Russo

Fundação Jorge Duprat Figueiredo de Segurança e Medicina do Trabalho: São Paulo, São Paulo, BR

E-mail: ana.russo@fundacentro.gov.br

ABSTRACT

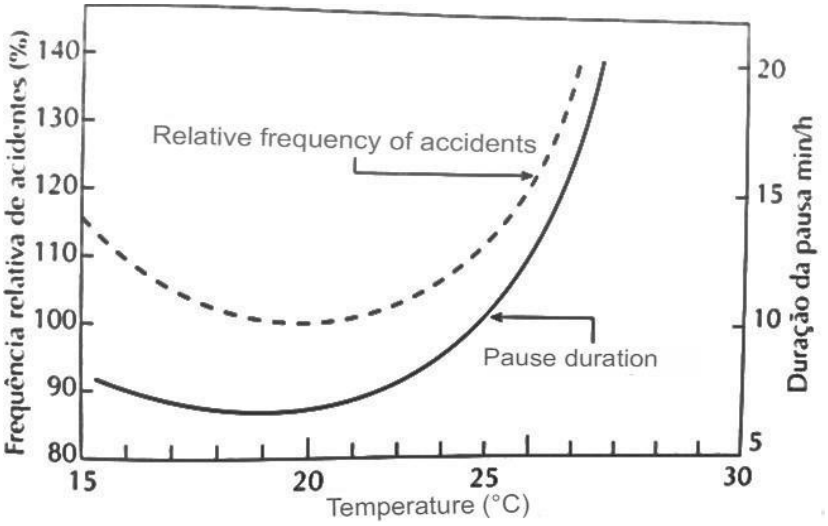
The police profession requires physical, psychological, and cognitive preparation. All these factors contribute negatively to the physical and mental comfort of these professionals. Considering that in summer the temperatures inside the vehicles, it exceed the range recommended by the Regulatory Standard (NR) 17, from 20 to 23°C (condition of thermal comfort), and that the police officers in radio patrolling activity generally do not make use of air conditioning. This paper proposed a thermal stress analyze during the police work, under the light of the theory and a case of study, during the performing of radio patrol services in Caraguatatuba (north coast) and Santos (south coast) in Sao Paulo State. The data obtained show that there is an imminent need to adapt the activity to improve the condition of thermal comfort within the vehicles.

KEYWORDS: Thermal Stress, NR 17, Risk Analysis.

1. INTRODUCTION

The work environment, influenced by market demands, high productivity, and intense competitiveness, can trigger various negative effects on the health of rural workers, including those in viticulture. Unfavorable environmental conditions, such as excessive heat, serve as sources of work-related stress, causing discomfort, increasing the risk of accidents, and potentially harming health (IIDA and BUARQUE, 2016). Figure 1 illustrates the growth of the relative frequency of accidents in relation to the increase in temperature.

Figure 1 - Influence of ambient temperature on a coal loading task



Source: (IIDA e BUARQUE, 2016)

Work should be carried out within the thermal comfort zone, which can be defined as the well-being sensation experienced by a person as a result of the satisfactory combination, in that environment, of variables such as relative humidity (RH) and ambient temperature (AT) with the activity carried out and the clothing worn by people (RUAS, 1999). Most of the literature on thermal comfort focuses on comfort related to built environments (BERMEJO et al., 2012; FILIPPÍN and FLORES LARSEN, 2012; KITOUS et al., 2012). Therefore, there is a need for research related to the thermal comfort of workers in mobile environments (MEDEIROS, 2014).

One increasingly common work environment in the 21st century is the car, used by drivers, taxi drivers, and even by the armed forces, as in the case of radio patrolling activities carried out by Military and Civil Police (MEDEIROS, 2014). The work of police officers, during their workday, requires not only physical fitness but also psychological and cognitive preparation (AÑEZ, 2003). In addition to the environmental aspects of the work, police officers are usually equipped with instruments such as weapons, handcuffs, batons, bulletproof vests, and their uniforms, significantly affecting the thermal comfort of individuals by increasing thermal resistance levels (SIMÕES, 2003). All these factors contribute negatively to the physical and mental comfort of individuals in this type of work (MEDEIROS, 2014).

Annually, from December to February, the "Summer Operation" takes place, reinforcing policing in 16 municipalities in the south and north coast of São Paulo. Considering that during the summer, temperatures inside the vehicles can exceed 25°C, and police officers on radio patrolling duty generally do not use air conditioning, as they keep the windows open, this study aimed to analyze the thermal stress conditions to which military police officers in

the state of São Paulo are subjected, in light of current standards and procedures (BRASIL, 1978a; FUNDACENTRO, 2001), when performing motorized radio patrolling services in Caraguatatuba (north coast) and Santos (south coast) at the 20th and 6th Military Police Battalion (BPMI), respectively.

2. MATERIALS AND METHODS

The collection of environmental variables (dry bulb temperature, wet bulb temperature, globe temperature, relative humidity, and ambient temperature) was performed by installing the calibrated thermal stress measuring device, HMTGD-1800, manufactured by HIGHMED (Figure 1), inside the vehicle to collect thermal data while the radio patrolling activity was conducted. This meter, in addition to measuring climatic variables, directly provides the values of the Wet Bulb Globe Temperature (WBGT) index, as established in NR15 and Occupational Hygiene Standards (NHO) 6 (BRAZIL, 1978a; FUNDACENTRO, 2001), and its operating range is between -20°C to +70°C.

Figure 2 - Thermal Stress Meter

Source: Author's own

As can be observed in Figure 2, the equipment was positioned at the center of the vehicle dashboard to collect information (every minute) as uniformly as possible, continuously for 24 hours (day and night shifts) over 6 days in each municipality (Caraguatatuba and Santos).

For the calculation of the Wet Bulb Globe Temperature Index (WBGT) (BRAZIL, 1978a; FUNDACENTRO, 2001), the condition of the internal environment was considered, meaning without direct solar load incidence since it is an assessment conducted inside the vehicle, as per Equation 1.

$$IBUTG = 0{,}7_{tbn} + 0{,}3_{ttt} \quad (1)$$

Em que:

- Tbn: natural wet bulb temperature ºC
- Tg: Globe temperature ºC

The determination of the maximum allowable Wet Bulb Globe Temperature (WBGT) is linked to the metabolic rate required for the labor activity, which can be obtained from NHO 6 (FUNDACENTRO, 2001). When a worker is exposed to two or more different thermal situations, the weighted average WBGT should be determined using Equation 2, with the representative WBGT values for the distinct thermal situations that make up the exposure cycle of the evaluated worker.

$$\overline{IBUTG} = \frac{IBUTG_1 \times t_1 + IBUTG_2 \times t_2 + \cdots + IBUTG_i \times t_i + \cdots + IBUTG_n \times t_n}{60} \quad (2)$$

em que:

- $\overline{IBUTG}$= Weighted average Wet Bulb Globe Temperature (WBGT) over time in °C
- IBUTGi= IBUTGi of thermal situation "i" in °C
- ti = total exposure time in thermal situation "i" in minutes, no
- most unfavorable 60 consecutive minutes period
- i = ith thermal situation t1 + t2 + ... + ti + ... + tn = 60 minutes

The occupational heat exposure limit is the maximum permissible Wet Bulb Globe Temperature (WBGT) value corresponding to the type of activity, determined based on the metabolic rate (M) for the assessed exposure condition, as shown in Table 1. This limit is applicable to healthy, acclimatized workers fully dressed in lightweight pants and shirt, with adequate water and mineral salts replenishment.

It is worth noting that the values used in Equation 2 correspond to the most unfavorable 60-minute period of the work shift, as required by NHO 6 (FUNDACENTRO, 2001).

Table 1 - Maximum Average WBGT Value for Each Metabolic Rate Level

Intermittent work schedule with rest at the workplace (per hour)	Light	Moderate	Heavy
Continuous work	Up to 30	Up to 26,7	Up to25,0
45 minutes of work, 15 minutes of rest	30,1 to 30,6	26,8 to 28,0	25,1 to 25,9
30 minutes of work, 30 minutes of rest	30,7ºC to 31,4	28,1 to 29,4	26,0 to 27,9
15 minutes of work, 45 minutes of rest	31,5ºC to 32,2	29,5 to 31,1	28,0 to 30,0
Work without the adoption of adequate control measures is not allowed	Above 32,2ºC	Above 31,1	Above 30,0

Source: NR15 (BRAZIL, 1978a)

In this article, the activity of radio patrolling was considered continuous and moderate (seated, vigorous movements with arms and legs). Thus, the established limit for the Wet Bulb Globe Temperature (WBGT) corresponds to a maximum value of 26.7 °C.

3. RESULTS

Table 2 and Figure 3 present the data obtained from the analyses conducted in Caraguatatuba

during the daytime period (06:00 to 18:00).

Table 2 – Average values of internal WBGT, Ambient Temperature, and Relative Humidity during the daytime shift in the municipality of Caraguatatuba (North Coast of SP)

Date	IBUTG (internal) °C	Ambient Temperature °C	UR %
06/01/2020	29,7	32,1	57,1
07/01/2020	34,6	40,5	35,3
08/01/2020	36,7	43,4	42,1
09/01/2020	34,6	39,5	43,9
10/01/2020	32,8	35,7	54,9
11/01/2020	41,1	47,9	40,5

Figure 3 - Average values of internal WBGT, Ambient Temperature, and Relative Humidity during the daytime shift in the municipality of Caraguatatuba (North Coast of SP)

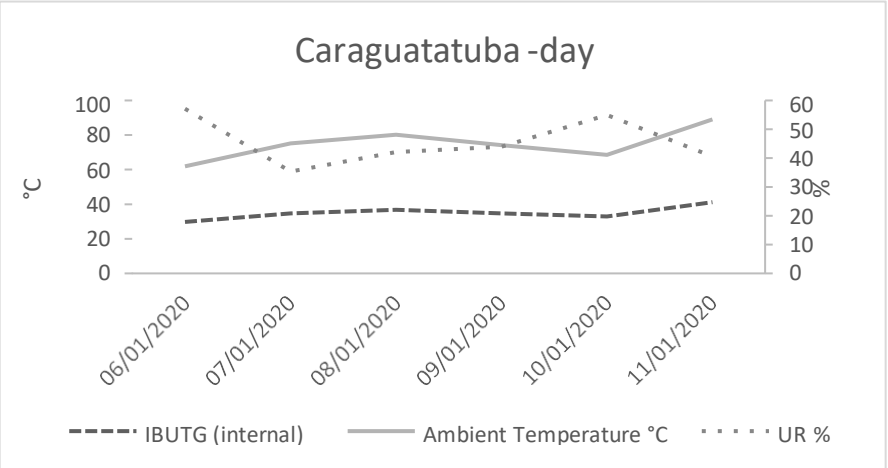
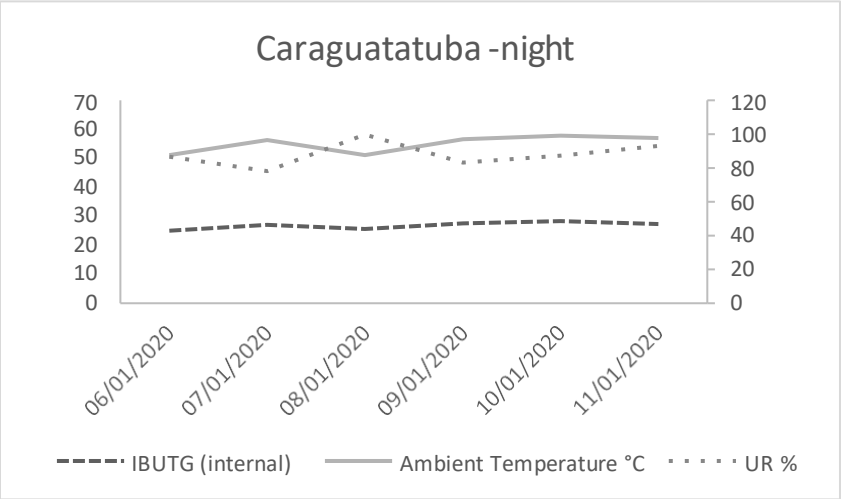


Table 3 and Figure 4 present the data obtained from the analyses conducted in Caraguatatuba during the nighttime period (18:00 to 06:00).

Table 3 – Average values of internal WBGT, Ambient Temperature, and Relative Humidity during the nighttime shift in the municipality of Caraguatatuba (North Coast of SP)

Date	IBUTG (internal) °C	Ambient Temperature °C	UR %
06/01/2020	25,0	26,1	86,6
07/01/2020	27,0	29,3	78,1
08/01/2020	25,6	25,5	99,7
09/01/2020	27,5	29,1	83,1
10/01/2020	28,3	29,5	87,2
11/01/2020	27,3	29,7	93,0

Figure 4 - Average values of internal WBGT, Ambient Temperature, and Relative Humidity during the nighttime shift in the municipality of Caraguatatuba (North Coast of SP)



As can be observed in Table 1, the maximum allowable WBGT would be 26.7,6 °C. Thus, as evident in Table 2, all sampled days (during the daytime period) exceeded the permissible value as specified in the standard. In the nighttime period (Table 3), the WBGT was exceeded on 4 out of the 6 days of analysis and exhibits high Relative Humidity, which hinders thermal exchange.

Table 4 and Figure 5 present the data obtained from the analyses conducted in Santos during the daytime period (06:00 to 18:00).

Table 4 – Average values of internal WBGT, Ambient Temperature, and Relative Humidity during the daytime shift in the municipality of Santos (South Coast of SP)

Date	IBUTG (internal) °C	Ambient Temperature °C	UR %
16/01/2020	36,6	46,3	31,1
17/01/2020	26,8	29,2	69
18/01/2020	28,6	32,8	61,9
19/01/2020	25,8	29,5	63,9
20/01/2020	31,0	37,3	41,4
21/01/2020	34,2	43,0	28,3

Figure 5 - Average values of internal WBGT, Ambient Temperature, and Relative Humidity during the daytime shift in the municipality of Santos (South Coast of SP)

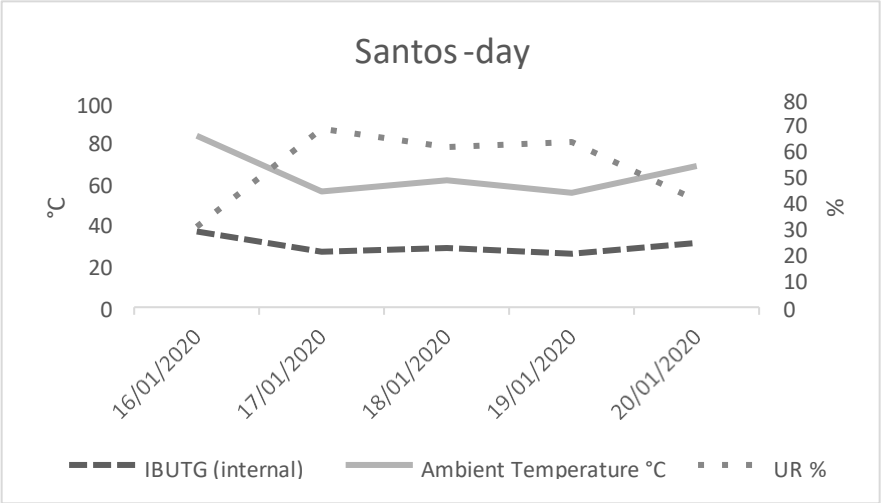
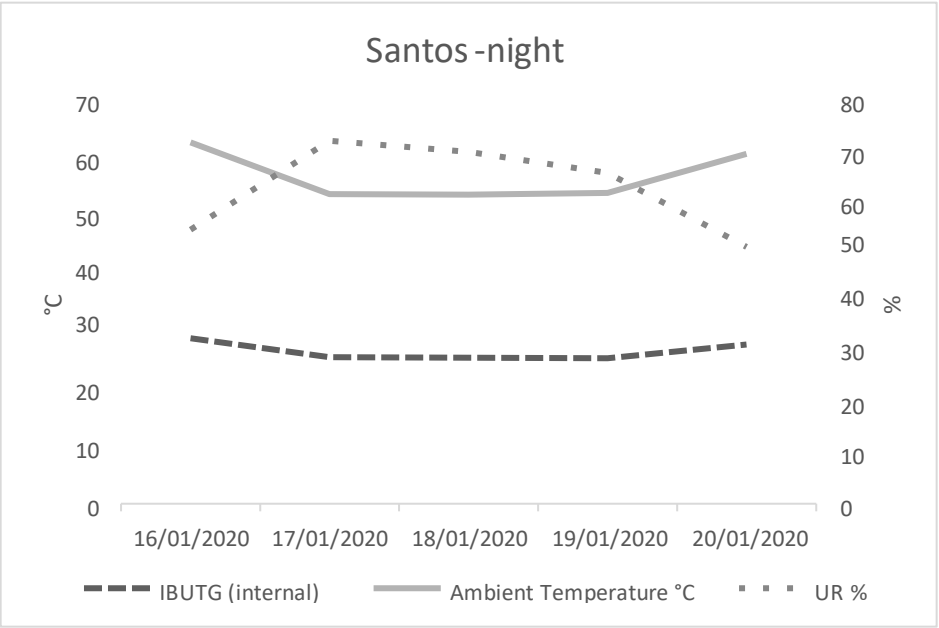


Table 5 and Figure 6 present the data obtained from the analyses conducted in Santos during the nighttime period (18:00 to 06:00).

Table 5 – Average values of internal WBGT, Ambient Temperature, and Relative Humidity during the nighttime shift in the municipality of Santos (South Coast of SP)

Date	IBUTG (internal) °C	Ambient Temperature °C	UR %
16/01/2020	28,8	34,1	54,5
17/01/2020	25,5	28,4	72,2
18/01/2020	25,4	28,4	70,0
19/01/2020	25,3	28,8	65,8
20/01/2020	27,7	33,2	51,1
21/01/2020	28,6	35,0	45,7

Figure 6 - Average values of internal WBGT, Ambient Temperature, and Relative Humidity during the nighttime shift in the municipality of Santos (South Coast of SP)



In Santos, only on January 19, 2020, during the daytime period (Table 4), did the WBGT value not exceed the permissible limit, while during the nighttime period (Table 5), the limit was exceeded on 3 out of the 6 days.

Regarding Ambient Temperature, all analyzed conditions exceeded the limit of 25 °C established by NR17 (BRAZIL, 1978b).

When considering the impact of clothing on the thermal comfort of police officers, it is necessary to make an adjustment to the WBGT limit. This correction is linked to the thermal insulation of the clothing, as indicated in Table 6.

Table 6 - Thermal insulation of police officers' clothing

Thermal insulation (Icl)	
Underwear	0,03 clo
T-shirt	0,19 clo
Jacket	0,69 clo
Pants	0,28 clo
Socks	0,03 clo
Boots	0,10 clo
Beret	0,01 clo
Vest (vest or body armor)	0,22 clo
Total	1,55 clo

The total thermal insulation of the clothing, as per the data presented in Table 6, was obtained by summing the respective insulation for each item of the police uniform (MEDEIROS, 2014).

The ORCBS - The Office of Radiation, Chemical, and Biological Safety (THE OFFICE OF RADIATION, 1999) provides correction values (Table 7).

Table 7 - Correction of WBGT for different types of clothing

Type of clothing	Value of Icl (clo)	Correction of WBGT (ºC)
Summer work uniform	0,6	0
Cotton cover	1,0	-2
Moisture protection, permeable	1,2	-4
Winter work uniform	1,4	-6

Source: ORCBS (The Office of Radiation, 1999)

Therefore, considering that the thermal insulation established for the clothing worn by military police officers in São Paulo during patrol activities was 1.55 clo (Table 6), and applying the correction proposed by the aforementioned authors, a correction of -6°C was adopted for the WBGT. Thus, by adjusting the Heat Exposure Limits specified in NR-15, considering the correct thermal insulation values, we have Table 8.

Table 8 - Heat exposure limits for patrol activity

Intermittent work schedule with rest at the workplace (per hour)	Moderate
Continuous work	Up to 20,7
45 minutes of work, 15 minutes of rest	20,8 a 22,0
30 minutes of work, 30 minutes of rest	22,1 a 23,4
15 minutes of work, 45 minutes of rest	23,5 a 25,1
Work without the adoption of adequate control measures is not allowed	Above 25,1

Source: Adapted from Regulatory Standard - NR 15 (BRAZIL, 1978a)

Therefore, considering the impact of clothing on the activity, the new limit of 20.7°C was exceeded in all conditions and environments analyzed in this study.

4. CONCLUSION

The results of the Wet Bulb Globe Temperature (WBGT) assessments indicate the imminent need for adjustments to the patrolling activities carried out during the Summer Operation. Both the northern and southern coastlines of the state of São Paulo showed values above the permissible standards during the analyzed period.

Therefore, it is suggested to adjust the thermal insulation of uniforms (using lighter materials to allow for greater heat exchange between the officers and the thermal environment) and to use air conditioning within the patrol vehicles.

5. REFERENCES

AÑEZ, Ciro Romelio Rodriguez. Sistema de avaliação para a promoção e gestão do estilo de vida saudável e da aptidão física relacionada à saúde de policiais militares. 2003. Universidade Federal de Santa Catarina , Florianópolis, 2003. Disponível em: <https://repositorio.ufsc.br/xmlui/bitstream/handle/123456789/84715/194330.pdf?sequence=1&isAllowed=y>. Acesso em: 13 fev 2020.

BERMEJO, Pablo e colab. Design and simulation of a thermal comfort adaptive system based on fuzzy logic and on-line learning. Energy and Buildings, v. 49, p. 367–379, Jun 2012.

BRASIL. Ministério do Trabalho e Emprego. Norma Regulamentadora no 15, de 08 de junho. . Brasil: [s.n.]. Disponível em: <http://trabalho.gov.br/images/Documentos/SST/NR/NR15/NR-15.pdf>. , 1978a

BRASIL. Ministério do Trabalho e Emprego. Norma Regulamentadora no 17, de 08 de junho. . [S.l: s.n.]. Disponível em: <http://trabalho.gov.br/images/Documentos/SST/NR/NR17.pdf>. Acesso em: 17 nov 2017b. , 1978

FILIPPÍN, C. e FLORES LARSEN, S. Summer thermal behaviour of compact single family housing in a temperate climate in Argentina. Renewable and Sustainable Energy Reviews. [S.l: s.n.]. , Jun 2012

FUNDACENTRO. Normas de Higiene Ocupacional NHO 06 - Avaliação da Exposição Ocupacional ao Calor. 2001. São Paulo: [s.n.], 2001. Disponível em: <http://www.fundacentro.gov.br/biblioteca/normas-de-higiene-ocupacional/publicacao/detalhe/2012/9/nho-01-procedimento-tecnico-avaliacao-da-exposicao-ocupacional-ao-ruido>.

IIDA, Itiro e BUARQUE, Lia. Ergonomia: Projetos e Produção. São Pauo: Blucher, 2016.

KITOUS, Samia e BENSALEM, Rafik e ADOLPHE, Luc. Airflow patterns within a complex urban topography under hot and dry climate in the Algerian Sahara. Building and Environment, v. 56, p. 162–175, Out 2012.

MEDEIROS, ELAINE GONÇALVES SOARES DE. Estudo termoambiental em viaturas utilizadas nos serviços de radiopatrulhamento no estado da paraíba. 2014. 1–130 f. Universidade Federal da Paraíba, 2014.

RUAS, Álvaro César. Conforto térmico nos ambientes de trabalho. [S.l.]: FUNDACENTRO,

1999. Disponível em: <file:///C:/Users/russo/OneDrive - Instituto Maua de Tecnologia/Disciplinas/Conforto Térmico nos Ambientes de Trabalho-pdf.pdf>.

SIMÕES, Márcia Clara. Formulação de um repositor hidroeletrolítico para o trabalho físico ostensivo de policiais militares, adaptado as variações climáticas de Florianópolis. 2003. Universidade Federal De Santa Catarina, Florianópolis, 2003. Disponível em: <https://repositorio.ufsc.br/bitstream/handle/123456789/86571/191995.pdf?sequence=1&isAllowed=y>. Acesso em: 13 fev 2020.

THE OFFICE OF RADIATION, Chemical and Biological Safety. Msu Employee Guidelines For Working In Hot Environments. [S.l: s.n.], 1999.

VERNON, H. M. e BEDFORD, T. The Relation of Atmospheric Conditions to the Working Capacity and the Accident Bate of Coal Miners. Industrial Fatigue Research Board Report. Medical Research Council, n. 39, 1927