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The relationship between the nasal cycle and axillary sweat production

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SUMMARY

Mean inspiratory nasal resistances and mean axillary sweating rates were recorded bilaterally every 30 minutes for a 5-7 hour period in seven subjects. One subject performed the experiment twice. Nasal resistance was measured using either anterior (n = 5) or posterior (n = 2) rhinomanometry and sweating rate was determined using a filter paper technique. The results for seven of the experiments showed that both nasal resistance and axillary sweating rate exhibited periodic reversals in side dominance. The cyclic patterns for nasal resistance and sweating rate were synchronized in phase in two experiments and 180 degrees out of phase in five experiments. These results support the concept of a central governing cycle with peripheral expression effected by the autonomic nervous system.

INTRODUCTION

The nasal cycle was brought to the attention of students of nasal physiology by Kaysar (1895) and remains a focus of study today. This cycle refers to the observed alternating resistances to airflow of the two nasal cavities and reflects the periodic reciprocal congestion and decongestion of the left and right nasal mucosa (Eccles, 1978). While the cycle is observed in approximately 80% of adults, the physiologic basis of its rhythm has not been defined completely (Eccles, 1978; Haight and Cole, 1984). Most evidences support Stoksted's (1952) suggestion that the periodicity of the cycle is controlled centrally by the hypothalamus with effects peripherally mediated by the autonomic nervous system (Eccles, 1978; Eccles and Lee, 1981; Eccles et al., 1979; Stoksted, 1953). Alternatively, one recent study reported a direct correlation between the lateralization of electrocortical activity and that of the nasal cycle which, if supported, defines the dependency of a well characterized peripheral autonomic function on cerebral dominance (Werntz et al., 1983).

These considerations led a number of investigators to suggest that other autonomically modulated bilateral functions should exhibit reciprocating cycles (Nilsson et al., 1982; Beickert, 1951; Uemura et al., 1980; Borjsen-Moller and Fahrenkrug, 1971). These include: pupillary dilation, blood vessel diameter, salivary gland output, body surface sweat production, and nasal secretion.

Indeed, blood flow through the cornea and over the middle ear promontory were reported to exhibit a bilaterally reciprocating cycle in phase with that of the nose (Beickert, 1951). The purpose of this experiment was to extend these observations to another autonomically controlled function. Specifically, we evaluated the hypothesis that the side dominance of the axillary sweating rate exhibits an alternating cycle which is temporally synchronized to the nasal cylce.

MATERIALS AND METHODS

Seven healthy adult males, aged 22–36 years, were enrolled in the study. Each had a routine ear, nose and throat examination prior to entry and, with one exception, all had normal unobstructed nasal airways. One individual had a left anterior septal deviation (Subject 7). Six of these subjects performed the experiment once and one subject (Subject 1) performed the experiment twice for a total of eight experiments. All experiments were conducted in the Ear, Nose and Throat Basic Research Laboratory. Room temperature was controlled centrally and ranged from 22°–24°C. All experiments were performed between the hours of 9:00 and 15:00 during the month of May. For each experiment, nasal airway resistance and axillary sweat production were measured periodically. Additionally, for two subjects, heart rate was monitored.

Each experiment consisted of a series of test sessions repeated every 30 minutes over a 5–7 hour period. For each session, the subjects were seated comfortably on a stool with their backs unsupported. The first 10 minutes were spent recording the EKG, where applicable, and conducting the sweat test. Rhinomanometric evaluations of nasal patency were then performed. The remaining minutes of the half hour were free of testing. During this time, the subject was permitted to stand and walk about, but did not leave the laboratory.

Nasal airway patency was evaluated using a computer-assisted rhinomanometric system developed in our laboratory. In two subjects (Subject 1 and subject 5), a posterior rhinomanometric technique was used (Graamans, 1980). For these tests, the subject's nose was fitted with a low-dead space mask serially aligned to a pneumotach. Airflow was measured by a differential pressure transducer in parallel with the pneumotach. Transnasal pressure was measured by a differential pressure transducer serially aligned between the mask and a oral catheter. Each nasal cavity was evaluated individually by masking the contralateral nostril with surgical tape. The remaining subjects could not satisfactorily perform this test and were evaluated using anterior rhinomanometry (Graamans, 1980). For these subjects, a plastic nozzle was substituted for the mask and was gently applied to the nostril to be tested. The oral catheter was replaced by a nasal olive which was applied against the contralateral nostril to estimate posterior nasopharyngeal pressure. Each test consisted of monitoring the transnasal pressure and airflow over a 40 second period of relaxed nasal breathing. Transducer signals were amplified, sampled every 20 milliseconds, digitized by an A-D converter board, and channeled to the memory of a microcomputer (IBM PC). Online monitoring of the subject's performance was available as a video display of the flow versus pressure plots for each breathing cycle. All sampled data for each test were stored on floppy disk. Task specific software allowed for the retrieval, editing and analysis of the collected data. A variety of a calculated parameters was available for study, including: work per liter, nasal power, and mean, mode or median resistances. The functions relating the values of these parameters to time were similar and data presentation is limited to mean inspiratory resistances. Total nasal resistance was calculated using the formula $R_t = (Rl^*Rr)/Rl + Rr)$.

The electrocardiogram was obtained from a single pericardial electrode. The signal was amplified and displayed on a strip chart recorder. The number of signals recorded over the 10-minute period was determined and divided by 10 to yield the average number of beats per minute for that test period.

The rate of sweating was determined using the filter paper technique described by Takagi and colleagues (Takagi and Kobayasi, 1955). Medium porosity circular filter paper disk (25 cm^2) were folded twice to form a triangular cone. The filter papers were fitted into the axillary regions and held by relaxed positioning of the arms for a period of 10 minutes. Immediately before and after the tests, the filter papers were weighed. Difference in weight was taken as the rate of sweat production expressed in mg^*cm^2/min units.

RESULTS

The data available for analysis consist primarily of longitudinal measures of nasal resistance and axillary sweating rate. These data are shown in Figure 1 for one subject who also had his heart rate monitored over the seven hour test period. All three functions exhibited a pattern of temporal change consistent with cyclic phenomena.

Longitudinal measures of heart rate for Subject 1 were characterized by relatively low initial values (65 beats/min), followed by an increase to a peak value of 85 beats/min and then a gradual decrease to the initial values (Figure 1a). The period of this cycle appeared to be about six hours with an amplitude of 20 beats/minute. While the initial increase occurred immediately after ingestion of a light lunch, the peak heart rate occurred more than two hours later. The pattern was similar to that recorded for a second subject where the cycle was characterized by a period of about 4.5 hours and an amplitude of eight beats/minute.

The nasal resistance for the left, right and total nasal cavity as a function of time for Subject 1 are shown in Figure 1b. These data show a pattern consistent with classic descriptions of the nasal cycle reported by other investigators. Here, there is a well-defined bilaterally alternating period of increased resistances. For the first 2.5 hours of study, the resistance of the left nasal cavity was elevated and that

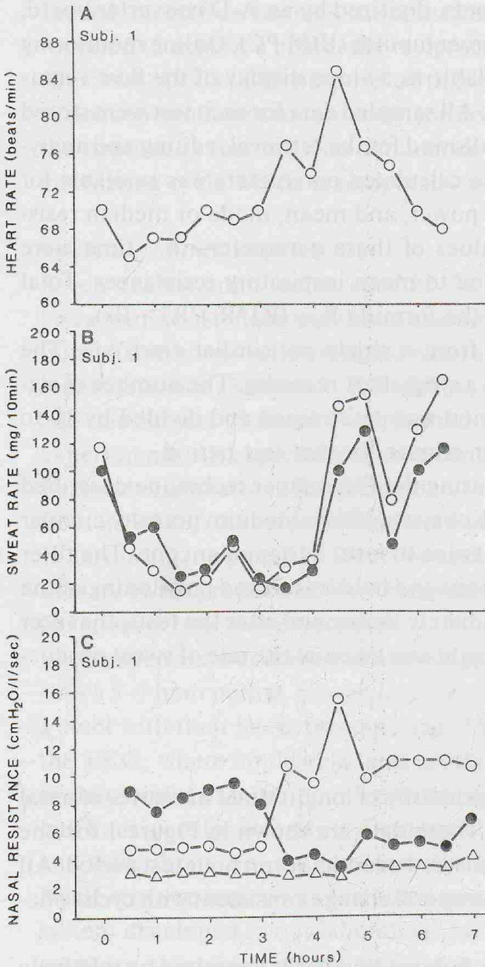


Figure 1. A longitudinal display of study data as a function of time for a 33-year-old male (Subject 1). Data are for: a. mean heart rate; b. left (filled circles) and right (open circles) axillary sweating rates; c. left (filled circles), right (open circles) and total (triangles) mean inspiratory nasal resistances.

of the right nasal cavity depressed. The reverse was true for the remainder of the study. The transition between dominance of the left and right nasal resistance was abrupt and well defined. The total resistance of the nose was constant over the period of study. Five of the eight experiments were characterized by a clearly defined "classic" nasal cycle. Two other experiments showed less well-defined reciprocating cyclic activity, and the data for the subject with the deviated nasal septum did not evidence a nasal cycle.

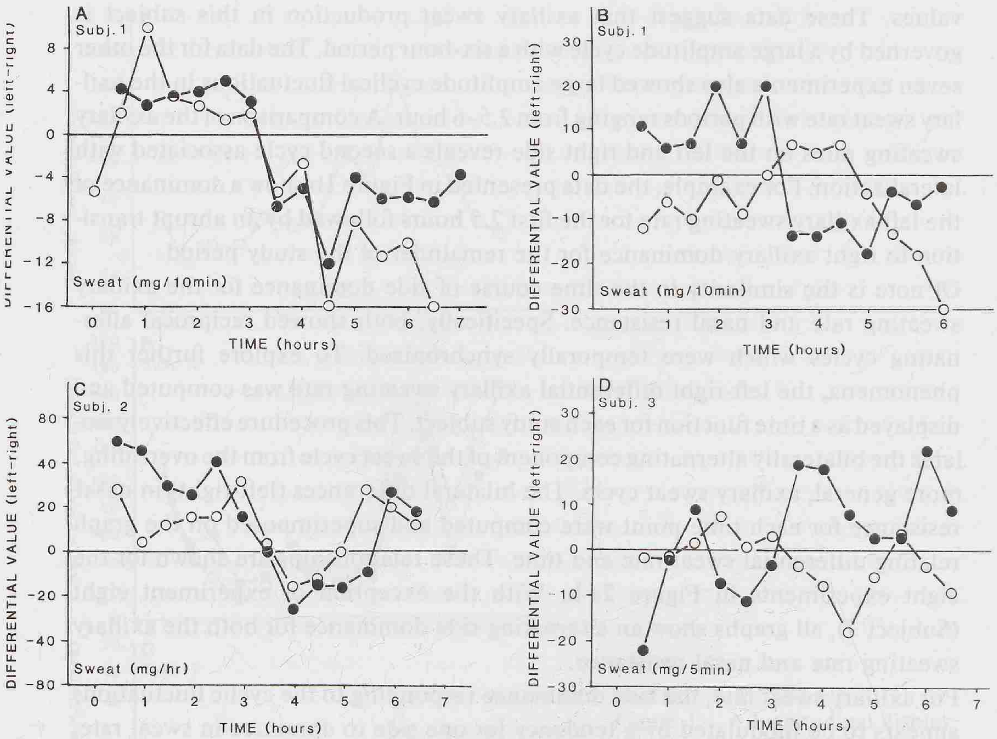
For the axillary sweating rate, data are shown for both the right and left axillary regions (Figure 1c). The overall pattern describing the sweating rate as a function of time is simular for the right and left axillary regions. The peak values occurred at about a six-hour interval and represent an 18-fold increase over the minimum values. These data suggest that axillary sweat production in this subject is governed by a large amplitude cycle with a six-hour period. The data for the other seven experiments also showed large amplitude cyclical fluctuations in the axillary sweat rate with periods ranging from 2.5–6 hour. A comparison of the axillary sweating rates on the left and right side reveals a second cycle associated with lateralization. For example, the data presented in Figure 1b show a dominance of the left axillary sweating rate for the first 2.5 hours followed by an abrupt transition to right axillary dominance for the remainder of the study period.

Of note is the similarity in the time course of side dominance for the axillary sweating rate and nasal resistance. Specifically, both showed reciprocal alternating cycles which were temporally synchronized. To explore further this phenomena, the left-right differential axillary sweating rate was computed and displayed as a time function for each study subject. This procedure effectively isolates the bilaterally alternating component of the sweat cycle from the overriding, more general, axillary sweat cycle. The bilateral differences (left-right) in nasal resistance for each time point were computed and superimposed on the graph relating differential sweat rate and time. These relationships are shown for the eight experiments in Figure 2a-h. With the exception of experiment eight (Subject 7), all graphs show an alternating side dominance for both the axillary sweating rate and nasal resistance.

For axillary sweat rate, the side dominance responding to the cyclic fluctuations appears to be modulated by a tendency for one side to dominate in sweat rate. This is most evident for the data presented in Figure 2e. Here, the sweat rate is either greater on the right side or equal between the sides. The cycle is reflected as a transition from right dominance to no dominance. A similar, though less extreme bias, was observed in the differential axillary sweat rate data for most experiments and for the differential nasal resistance for experiments 6–8. For the subject who had a septal deviation (Figure 2h), no bilateral alternating cycle was observed for either the nasal resistance or axillary sweat production. The nasal resistance was dominated by the left side while the rate of sweat production was dominated for the most of the time by the right side.

The data presented for experiments 1–7 show that the nasal resistance and axillary sweating rate undergo transitions in side dominance at approximately the same time. For example, in experiment 1, both the nasal resistance and sweating rate switch from left dominance to right side dominance at 2.5 hours into the experiment. This suggests that the cycles of the two functions are synchronized temporally. However, while the cycles for experiments 1 and 3 are in the phase, those of the remaining experiments are 180 degrees out of phase.

The results of repeated tests on one subject are displayed in the graphs for experiments 1 and 2 (Figures 2a, b) and show that the cycles are temporally locked in phase in one case and out of phase in the other.



DISCUSSION

The results of the present study show that the overall axillary sweating rate is characterized by a large amplitude, long period cycle which may reflect the basal metabolic activity of the individual. This contention is supported by the similarity in the functions relating both axillary sweat production and heart rate to time observed for the subject 1, experiment 1 (Figure 1).

After appropriate correction for the overall rate of axillary sweat production, a reciprocally alternating side dominance of the axillary sweating rate could be demonstrated. This was shown to be synchronized temporally with the periodic fluctuations observed for the nasal cycle. Previous studies showed that other autonomically modulated bilateral functions exhibited cyclic alternations in phase with the nasal cycle (Beickert, 1951). The synchronicity of the cycles governing the side dominance of these diverse autonomically modulated functions suggest that they represent the peripheral expression of a more central regulatory cycle.

Moreover, other evidences show this central cycle to be responsive to peripheral feedback control. For example, ipsilateral stimulation of skin pressure receptors

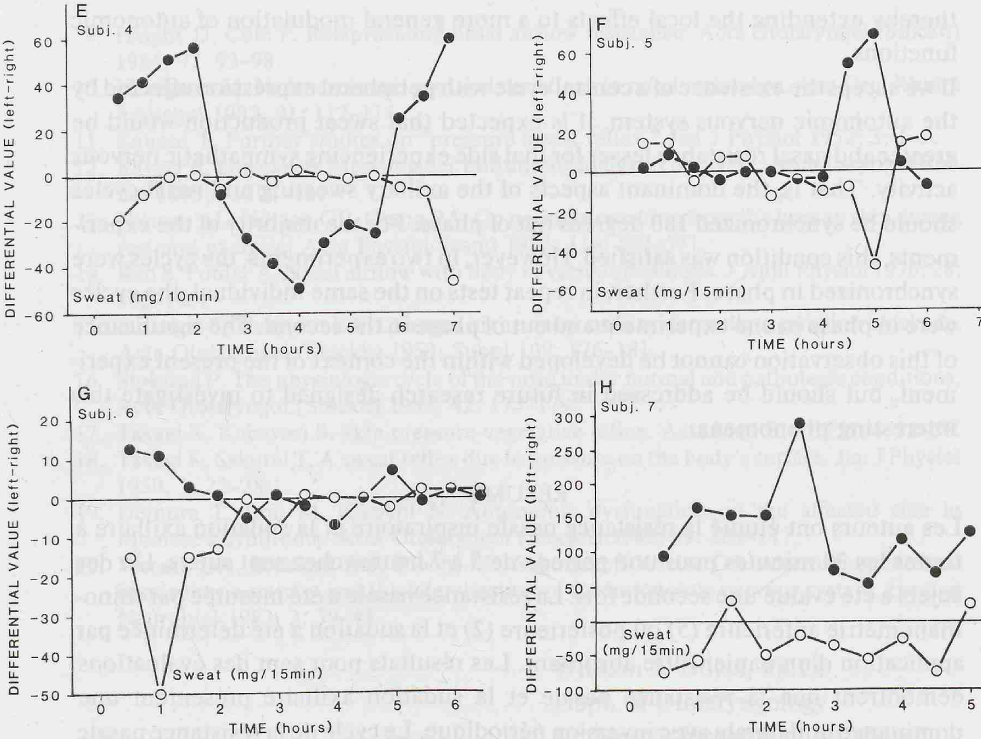


Figure 2. Differential (left minus right) mean inspiratory nasal resistances (filled circles) and axillary sweating rate (open circles) as a function of time for the eight experiments (a-h). Experiments designated "a" and "b" were repeat tests conducted on one individual (Subject 1). The experiment designated "h" represents data for the subject with a left nasal septal deviation (Subject 7).

results in a contralateral increase in nasal patency which, if maintained, resets the timing of the nasal cycle (Rao and Potdar, 1970; Hasegawa, 1982; Bhole and Karambelkar, 1968). Similarly, for sweat production, an ipsilateral increase in body surface sweat production to a contralateral applied surface pressure stimulation has been described as the hemihydrotic reaction (Takagi and Sakurai, 1950; Kauase, 1952). Others reported that the nasal cycle is abolished by adoption of alternative breathing patterns, such as those employed by chronic mouth breathers, patients with tracheostomy tubes, or patients with a unilateral deviated nasal septum (Cole, 1982). In this regard, it is interesting that the one patient in the present study with a deviated nasal septum exhibited neither a side dominant sweat cycle or nasal cycle. Rather, the nasal resistance was dominated by the left nasal cavity and the axillary sweating rate by the right axilla. If supported by future studies with additional patients, these results suggest that a functional change in nasal breathing patterns exerts a feedback control on the central cycle,

thereby extending the local effects to a more general modulation of autonomic functions.
If we accept the existence of a central cycle with peripheral expression effected by the autonomic nervous system, it is expected that sweat production would be greater and nasal resistance lesser for that side experiencing sympathetic nervous activity. That is, the dominant aspects of the axillary sweating and nasal cycles should be synchronized 180 degrees out of phase. For the majority of the experiments, this condition was satisfied. However, in two experiments, the cycles were synchronized in phase. Further, in repeat tests on the same individual, the cycles were in phase in one experiment and out of phase in the second. The significance of this observation cannot be developed within the context of the present experiment, but should be addressed in future research designed to investigate this interesting phenomena.

RÉSUMÉ

Les auteurs ont étudié la résistance nasale inspiratoire et la sudation axillaire à toutes les 30 minutes pour une période de 5 à 7 heures chez sept sujets. Un des sujets a été évalué une seconde fois. La résistance nasale a été mesurée par rhinomanométrie antérieure (5) ou postérieure (2) et la sudation a été déterminée par application d'un papier filtre absorbant. Les résultats pour sept des évaluations démontrent que la résistance nasale et la sudation axillaire présentent une dominance unilatérale avec inversion périodique. Le cycle de la résistance nasale et de la sudation étaient en phase dans deux expériences et déphasées de 180° dans cinq autres. Ces résultats supportent la théorie d'existence d'un cycle central avec expression périphérique de système nerveux autonome.

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