Eur Respir J, 1993, 6, 1449–1454
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European Respiratory Journal
ISSN 0903 - 1936

Voluntary cough suppression as an indication of symptom severity in upper respiratory tract infections

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ABSTRACT: The aim of the present study was to determine whether the ability to suppress cough voluntarily is an index of cough severity in upper respiratory tract infection.

Cough was measured by means of a microphone linked to a pen recorder and subjects were instructed to voluntarily suppress cough in order to determine cough suppression time. Subjective scores of symptom severity, mood and psychological parameters were made prior to cough measurements.

The baseline frequency of cough showed a distribution towards the higher frequencies, with a median of 2.1 (lower quartile 1.2, upper quartile 3.2) coughs·min^{-1}. The results for cough suppression fell into two distinct groups, one group reaching a breaking point within 12.6 min; and another group which did not cough during the 20 min cough suppression period. In the group of subjects which broke from the cough suppression, there was an inverse relationship between the cough suppression time and the baseline frequency of cough. The median frequency of cough following cough suppression was significantly greater than the baseline median frequency of cough.

The subjects who reached a breaking point had a greater baseline frequency of cough and a greater symptom severity score, and they also felt more feeble, clumsy, sad and antagonistic than the group which did not reach a breaking point. The subjects who reached a breaking point had significantly greater scores for the psychology parameter of obsessional symptoms than the group which did not reach a breaking point.

These results demonstrate that there is considerable ability to voluntarily suppress cough, and that the degree of voluntary suppression is related to the severity of cough and to psychological factors such as obsessional symptoms.
Eur Respir J., 1993, 6, 1449–1454.

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Keywords: Common cold
cough
cough suppression

Received: November 5 1992
Accepted after revision June 16 1993

Cough is a defensive respiratory reflex, which is important for the expulsion of excessive mucus and inhaled foreign bodies from the airways. Cough is also a common and irritating symptom associated with upper respiratory tract infection, and in most instances this type of dry irritating cough does not appear to be in any way defensive or beneficial. Unlike sneeze, which is a reflex response with little or no voluntary control, cough can be initiated at will and can be voluntarily suppressed, at least for a time, when it is inconvenient to cough. If there is considerable voluntary suppression of cough, then it is important to consider this as a complicating factor in cough clinical trials, where the frequency and severity of cough may be measured as a means of screening antitussive medications. However, the evidence for voluntary suppression of cough is anecdotal. Many investigators have suggested that there is considerable voluntary suppression of cough [1–4], but there are no studies in the literature which have specifically investigated voluntary cough suppression, although there is evidence for voluntary suppression of capsaicin-induced cough [5].

Recent research has shown that psychological characteristics are important in susceptibility to illness and in the severity of symptoms. For example, it has been demonstrated that introverts were more liable to infection with cold producing viruses than extroverts, and that people with high scores for obsessional symptoms have a greater use of handkerchiefs when suffering from colds than those with low scores [6].

The aim of the present study was to investigate the degree of voluntary suppression of cough in upper respiratory tract infection, and to determine if symptom severity and psychological factors, such as mood and personality, influenced the duration of voluntary cough suppression.

Subjects and methods

Subjects

Volunteers were recruited from the student population of the University of Wales College of Cardiff and the general population of the City of Cardiff for a study on "cough suppression".

A total of 79 volunteers with cough due to upper respiratory tract infection were included in the study (44 females, 35 males, mean age 24 yrs). The mean duration of cough symptoms was 5.5 days, range 1–28 days.

Volunteers were excluded from the study if they: were not within the age range of 18–60 yrs; had clinical evidence of lower respiratory tract infection or asthma; had a clinically significant cardiovascular, urological or neurological disease; had taken a product containing menthol in the previous 6 h, were pregnant or lactating; or if they had taken any medication (apart from the contraceptive pill) in the previous 24 h.

The volunteer first read an information sheet, which briefly outlined the stages involved in the trial, filled out a questionnaire requesting details of cough history, and then gave informed consent for the study. They were then examined by the clinician, to determine their state of health and suitability for the trial. If the volunteer was considered suitable, they were then asked to complete two further questionnaires. One of these was a subjective scaling questionnaire, in order to determine the severity of various symptoms including cough, and the other was a psychology questionnaire consisting of three parts. Firstly, the Eysenck Personality Inventory was used to measure the stable traits of introversion (and its sub-scales of impulsivity and sociability) and neuroticism. Secondly [6], a revised version of the Middlesex Hospital Questionnaire was used to measure the presence of mild psychoneurotic symptoms in the past 6 weeks. The final measure examined mood at the time of testing [7]. Bi-polar visual analogue scales for mood and for the effort and demand required to suppress cough were also made.

Method

For the duration of the trial, the volunteers were seated in a comfortable chair and watched a video film. A monitor screen was set up above the television which carried three instructions: "Please cough once only"; "Please do not cough"; and "Just relax and cough if you wish". The individual boxes illuminated as required to direct the appropriate command. Before beginning the trial, the volunteer was instructed to carefully watch the monitor screens and to carry out the instructions as indicated. The sequence of instructions to volunteers and a flow diagram of the experiment is shown in figure 1.

During the first 30 min, the volunteer was given the instruction "Just relax and cough if you wish". The cough frequency was measured by means of a Lafayette Datagraph ink pen recorder. A microphone placed on the floor in front of the volunteer recorded individual coughs as spikes

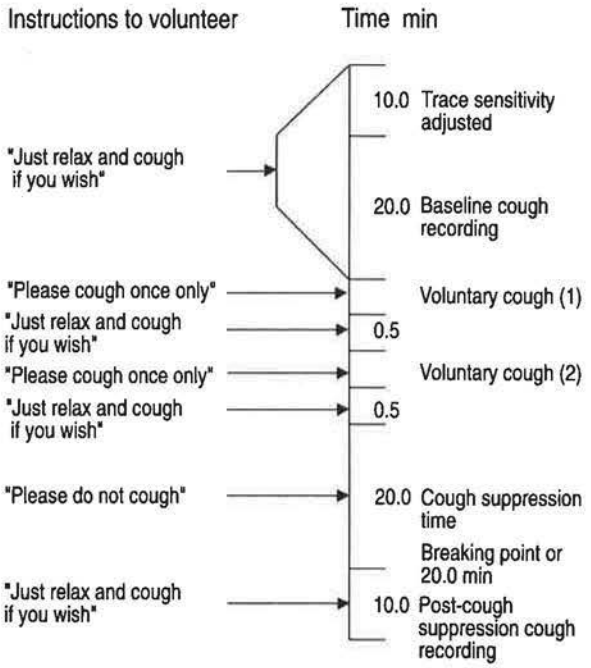

Fig. 1. – Flow diagram of the steps involved in the cough suppression trial.

of varying amplitude on the pen recorder. An integrated sound response (with a time constant of 0.02 s) from the microphone was recorded on a moving paper trace at a speed of 40 mm·min^{-1}. The first 10 min of recording were used to adjust the sensitivity of the pen recorder to produce spikes of almost maximum amplitude on the trace. The baseline frequency was then recorded for the remaining 20 min.

At the end of the 20 min baseline period, the volunteer was given the instruction "Please cough once only". There was then a 30 s interval where the volunteer was instructed to "Just relax and cough if you wish". This was followed by the instruction "Please cough once only", which was in turn followed by another 30 s interval where the volunteer was instructed to "Just relax and cough if you wish". The two voluntary coughs preceded the period of voluntary cough suppression, to ensure that all subjects started the cough suppression under similar conditions. Without this precaution, the incidence of coughing prior to the period of cough suppression would not have been controlled.

After the two voluntary coughs the volunteer was given the instruction "Please do not cough". The volunteers had no idea how long they would have to suppress their coughs, and they could not see a stop-clock. However, the volunteers were free to cough whenever they wished. Due to time constraints, the maximum time period of cough suppression was 20 min. After this 20 minute period, or if the volunteer coughed within this period, the volunteer was given the instruction "Just relax and cough if you wish". The frequency of cough was then recorded for 10 min following the period of voluntary cough suppression.

The objective parameters recorded for each volunteer were baseline coughs per minute, cough suppression time in minutes, and cough frequency in the period following

cough suppression. In addition, mood visual analogue scales, subjective symptom severity scores and stable psychology parameters were recorded.

The trial was approved by the local Hospital Ethics Committee.

Cough counting method

The cough frequency was calculated for each pen recorder trace according to the following criteria:-

1. The largest single pen recorder deflection was selected.
2. Confirmation was made that there were at least two more pen deflections of this maximum deflection.
3. If there were not, then the next three largest deflections were selected, and an average of these three values was taken to calculate the mean maximum deflection in mm.
4. A cough was counted if the pen recorder deflection in mm was at least one third the height of the mean maximum deflection as measured during the baseline period.

A Macintosh "Statview II" package was used to calculate the statistics. Results were expressed as median (with lower and upper quartiles), and nonparametric Mann-Whitney U-tests were used to compare sets of data. Spearman rank correlation coefficients were used throughout for testing associations between various measured parameters.

Results

The median (lower and upper quartile) frequency of cough during the baseline period was 2.1 (1.2, 3.2) coughs·min^{-1}, and the frequency distribution graph for all subjects at baseline is illustrated in figure 2.

Cough suppression

Following the baseline period of cough recording, subjects were instructed to refrain from coughing, and of the 79 subjects entered into the trial, 52 subjects coughed within the 20 min period. The median (lower and upper quartile) duration of cough suppression within this group was 3.2 (1.2, 8.9) min, range 0.4–12.6 min. The remaining 27 subjects did not cough within the first 20 min. Figure 3 shows the frequency distribution of cough suppression time for all subjects, and demonstrates that the subjects fell into two distinct groups; a group which reached a cough breaking point within 12.6 min (n=52), and a group which suppressed cough for longer than 20 min (n=27). The results for these two groups have been analysed separately.

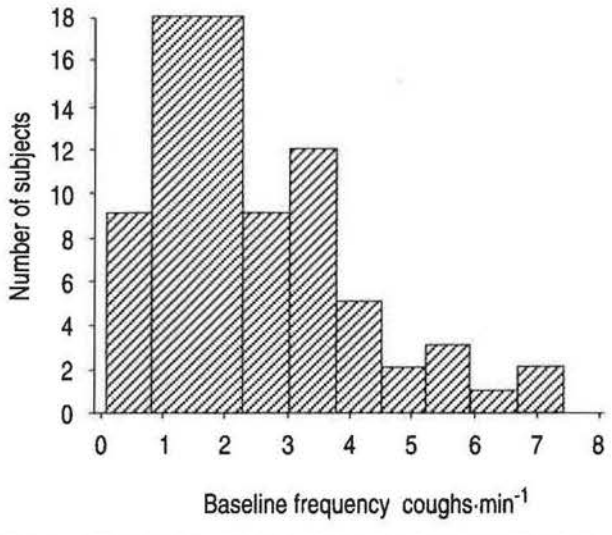

Fig. 2. – Frequency distribution of the baseline frequency of cough in all 79 subjects.

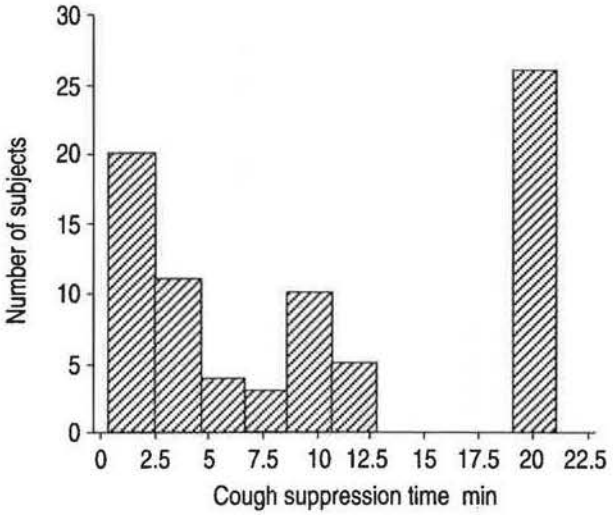

Fig. 3. – Frequency distribution of cough suppression time in all 79 subjects.

Group which reached a cough breaking point

In the group of 52 subjects who coughed within the 20 min period, there was an inverse relationship between the suppression time and the baseline frequency of cough as illustrated in figure 4 (Rho corrected for ties=-0.43, p=0.0024). Following the break from cough suppression, the subjects were instructed to "Just relax and cough if you wish". The median (lower and upper quartile) frequency of cough following cough suppression was 3.5 (2.2, 5.4) coughs·min^{-1}, which was significantly greater than the baseline median cough frequency of 2.6 (1.7, 3.6) (p=0.001, n=52). There was a direct relationship between the baseline frequency of cough and the post-cough suppression frequency of cough, as illustrated in figure 5 (Rho corrected for ties=0.7, p=0.0001).

No relationship was found between any of the objective measures of cough severity (baseline frequency, cough suppression time, post-cough suppression frequency) and the subjective scores of symptom severity. Similarly, no relationship was found between the objective measures of cough severity and the psychology scores for mood and personality. However, the subjective scores for symptom severity were significantly correlated to the mood scores, as listed in table 1.

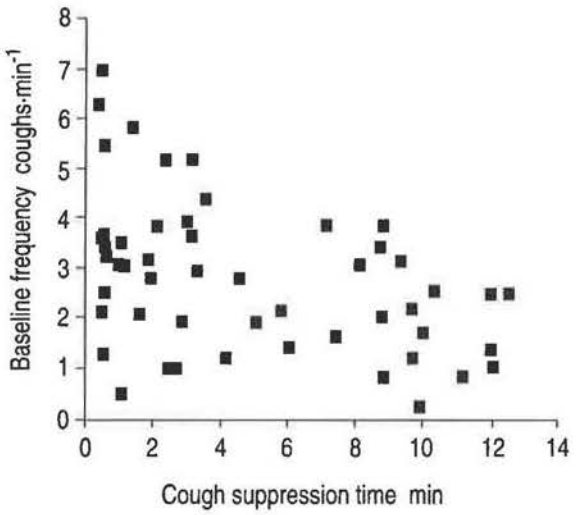

Fig. 4. – The relationship between the cough suppression time and the baseline frequency of cough, from the group of 52 subjects who broke from the period of cough suppression. (Rho corrected for ties=-0.43, p=0.0024).

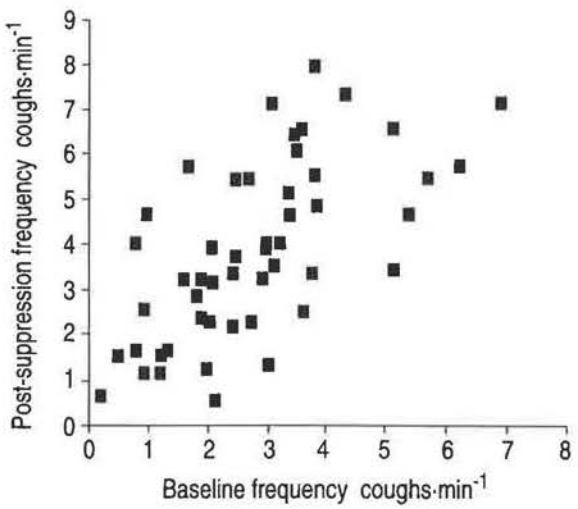

Fig. 5. – The relationship between the baseline frequency of cough and the frequency of cough following a period of cough suppression, from the group of 52 subjects who broke from the period of cough suppression. (Rho corrected for ties=0.7, p=0.0001).

Table 1. – The relationship between the mood ratings and median symptom severity scores for the 52 subjects breaking from the period of cough suppression (Spearman rank correlation coefficients)

Mood scale	Symptom severity	
	Rho	p
Drowsy (0)/alert (100)	-0.42	0.0025**
Muzzy (0)/clear-headed (100)	-0.5	0.0005***
Discontented (100)/contented (0)	0.4	0.0053**
Mentally slow (0)/quickwitted (100)	-0.38	0.0074**
Dreamy (100)/attentive (0)	0.37	0.0081**
Incompetent (0)/proficient (100)	-0.4	0.0042**
Sad (100)/happy (0)	0.35	0.012*
Bored (100)/interested (0)	0.36	0.012*

Mood ratings were scored on 100 mm visual analogue scales, with the extremes of each mood placed at 0 and 100 mm. The mood scales are arranged in the table to show the relationship between them and the symptom severity scores. In general, as the mood scales on the far left of the table increase, there is a resulting increase in the symptom severity score. NS: $p>0.05$; *: $p\leq0.05$; **: $p\leq0.01$; ***: $p\leq0.001$.

Table 2. – A comparison of the cough measurements and subjective scores between the group which broke from a period of cough suppression and the group which did not cough within the 20 min cough suppression period (derived from the Mann-Whitney U-test)

	Cough break group n=52	No cough group n=27	p-value
Baseline cough frequency	2.6 (1.7, 3.6)	1.4 (0.9, 2.1)	0.0014**
Post-cough-suppression cough frequency	3.5 (2.2, 5.4)	1.8 (1, 3)	0.0072**
Ratio post-suppression/baseline	1.35	1.29	
Symptom severity	1.5 (1, 2)	1 (0.5, 1.5)	0.007**
Cough severity	2 (2, 3)	2 (1, 2)	0.053 (NS)
Effects on concentration	2 (1, 2)	1 (1, 2)	0.04*
Obsessional symptoms	2 (2, 3)	1.5 (1, 3)	0.009**
Relaxed/excited	30 (22, 46.5)	24.5 (10, 32)	0.017*
Strong/feeble	62.5 (48, 73)	45.5 (22, 58)	0.003**
Well-coordinated/clumsy	53.5 (36, 63.5)	38 (17, 46)	0.0035**
Incompetent/proficient	53 (40.5, 64)	69.5 (50, 79)	0.017*
Happy/sad	41 (25.5, 52)	26 (13, 46)	0.040*
Antagonistic/friendly	67.5 (50, 78)	78 (64, 85)	0.017*
Contented/discontented	47.5 (25.5, 65)	33.5 (9, 55)	0.06 (NS)
Withdrawn/sociable	51 (40, 69)	71 (41, 77)	0.05 (NS)
Cough control			
Not at all demanding/very demanding (before)	52 (34.5, 68.5)	38 (17, 53)	0.01*
Not at all demanding/very demanding (after)	60.5 (40, 72.5)	27.5 (17, 61)	0.002**
Little or no effort/maximum effort (before)	54.5 (40, 71.5)	37.5 (18, 62)	0.01*
Little or no effort/maximum effort (after)	61.5 (47, 73.5)	34.5 (21, 57)	0.0002***

In the table, the moods placed on the extreme left of the table represent scores of 0 on the visual analogue scale, and those on the right scores of 100. All values are expressed as median (with lower and upper quartiles in parenthesis). NS: $p>0.05$; *: $p\leq0.05$; **: $p\leq0.01$; ***: $p\leq0.001$.

Table 3. – The relationship between mood ratings and median symptom severity scores for all subjects (Spearman rank correlation coefficients)

Mood scale	Symptom severity Rho	p
Drowsy (0)/alert (100)	-0.44	0.0001***
Feeble (100)/strong (0)	0.4	0.0004***
Muzzy (0)/clear-headed (100)	-0.6	0.0001***
Clumsy (100)/well-coordinated (0)	0.5	0.0001***
Lethargic (0)/energetic (100)	-0.4	0.001**
Discontented (100)/contented (0)	0.5	0.0001***
Troubled (0)/tranquil (100)	-0.4	0.0004***
Mentally slow (0)/quickwitted (100)	-0.4	0.0006***
Dreamy (100)/attentive (0)	0.4	0.0009***
Incompetent (0)/proficient (100)	-0.53	0.0001***
Sad (100)/happy (0)	0.5	0.0001***
Antagonistic (0)/friendly (100)	-0.4	0.0007***
Bored (100)/interested (0)	0.4	0.0011**

Extremes of mood are placed at 0 and 100 mm on the visual analogue scales. In general, as the mood scales on the far left of the table increase, there is a resulting increase in the symptom severity scores. NS: $p>0.05$; *: $p\leq0.05$; **: $p\leq0.01$; ***: $p<0.001$.

Comparison between the group that reached a cough breaking point and the group which did not cough

The group which coughed within the first 20 min had a significantly greater baseline frequency of cough (p=0.0014) and post-cough suppression frequency of cough (p=0.0072) than the group which did not cough, as listed in table 2. The ratio between the frequency of cough following cough suppression and that prior to cough suppression was 1.35 in the cough break group and 1.29 in the group which did not cough during the first 20 min.

The cough break group had significantly greater scores, for symptom severity (p=0.007), and effects on concentration (p=0.04), than the group which did not cough, and similarly the cough break group was significantly more excited, feeble, clumsy, incompetent, sad and antagonistic, as listed in table 2. The cough break group also scaled before and after the cough suppression on bi-polar visual analogue scales that they required more demand and effort to control cough than the group which did not cough. The scores for the psychology parameter of obsessional symptoms were significantly higher in the group breaking from a period of cough suppression (p=0.009). This difference was not observed with any of the other psychology parameters.

Mood ratings were related to the symptom severity in all 79 subjects (table 3).

Discussion

The results of the present study clearly demonstrate that cough due to upper respiratory tract infection can be suppressed. The degree of voluntary suppression can be measured as a cough suppression time, with the majority of subjects reaching a breaking point within 12.6 min. However, a significant number of subjects completely suppressed cough until they were prompted that they were free to cough if they wished. The maximum cough suppression time was arbitrarily set at 20 min and, perhaps, some of the latter group would have reached a breaking point if the duration of cough suppression had been extended. This seems unlikely, however, as there was a clear division between the two groups, with no subjects coughing between 12.6 min and the end of the cough suppression at 20 min. The clear division of subjects into two groups cannot be explained simply by differences in cold symptom severity. The frequency distribution curves for objective and subjective measures of cold and cough severity did not show any trend to split into two groups. However, the group which could not suppress cough had significantly more severe cough symptoms, as measured by the baseline frequency of cough and subjective scores of symptom severity. The clear division of cough suppression time into two distinct groups indicates that the ability to suppress cough operates on an all-or-none characteristic, according to the level of symptom severity. When symptom severity is high, the subjects are unable to completely suppress cough and there is an inverse relationship between cough suppression time and symptom severity. When symptom severity is low, subjects can completely suppress cough and cough suppression time cannot be related to symptom severity.

The voluntary suppression of cough and the ability to suppress cough may be related to mood and psychological parameters, but it is often difficult to separate these parameters from symptom severity. With severe cold symptoms one would expect changes in mood, so it is not surprising that this study showed that mood ratings were directly related to symptom severity. The two groups of subjects had significantly different symptom severity scores, and similarly they had significantly different mood scales. However, an interesting finding was that the group which broke from cough suppression had a significantly greater score for obsessional symptoms than the group which did not cough within the 20 min period. The score for obsessional symptoms was not related to symptom severity, and may be an independent stable characteristic which is not related to the disease state.

It is of interest that the same dimension that was related to use of handkerchiefs in subjects with colds, that of obsessional symptoms, should also be important in the ability to suppress cough [6]. Subjects with higher scores for obsessional symptoms may have a lower threshold at which voluntary behaviour such as nose-blowing or coughing is deemed necessary. There may also be differences between the extent to which subjects with high levels of obsessional symptoms selectively attend to the irritating stimulus and other features of the test situation (*e.g.* the video). Further experiments are necessary to clarify these mechanisms, but at the moment one can conclude that it is important to consider psychological characteristics in situations which involve voluntary forms of symptomatic behaviour, such as coughing, and trials which examine the effects of medication on these functions. The division of the subjects into two groups may be related to psychological factors, rather than the pathophysiology, and it does not appear to be related to the study design, as all the subjects were blinded to the duration of the period of cough suppression and were not aware of the 20 min time limit.

The mechanism behind the voluntary suppression of cough is uncertain. Figure 6 shows a diagram of the cough reflex arc. Under normal conditions, sensory information from irritant receptors is processed by the "cough centre". The sensory input is summated by the "cough centre" until a threshold level is reached, which then leads to coughing. Summation of the afferent impulses has previously been suggested as a mechanism for cough [8, 9]. Experiments in conscious guinea-pigs provided evidence of a remarkable ability of the "cough centre" to store afferent impulses [3]. Voluntary suppression of the cough centre allows voluntary coughs or voluntary inhibition of coughing. If coughing is voluntarily inhibited, then the duration of this cough suppression time will presumably be related to the rate at which sensory input is summated in the "cough centre". The severity of the upper respiratory tract infection determines the rate of sensory input to the "cough centre" and this input can be estimated by the baseline cough frequency when coughing occurs freely without any voluntary facilitation or inhibition of cough.

The correlation between the frequency of cough before cough suppression and the frequency of cough after a period of cough suppression supports the hypothesis that the "cough centre" summates afferent impulses. Not only was there a highly significant relationship between these parameters but also the frequency of cough after a period of cough suppression was increased compared to the baseline frequency of cough.

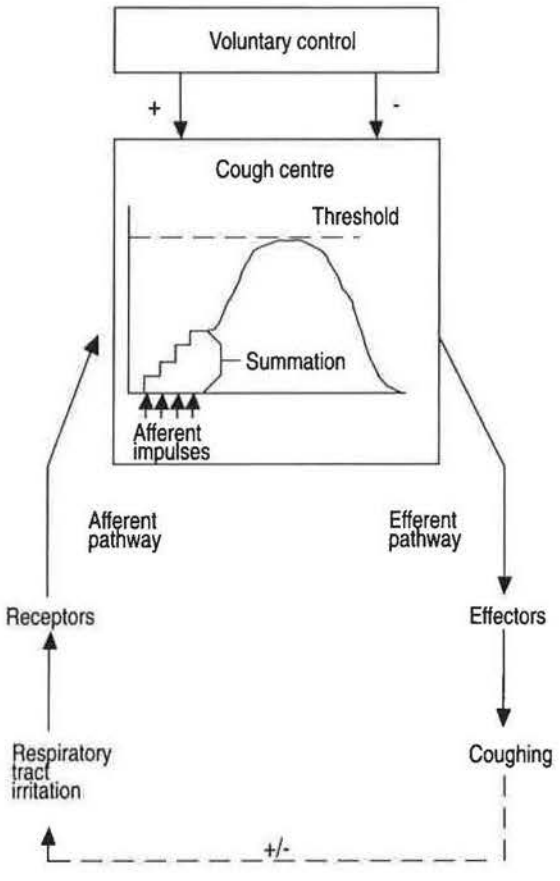

Fig. 6. – The cough reflex mechanism.

The voluntary suppression of cough may raise the threshold for cough, and the cough occurs when the afferent input from sensory receptors summates to the new threshold. Cough frequency is increased following a period of cough suppression, and this may be due to the cough threshold now decreasing back towards a lower level, plus the expression of the increased cough drive, which represents an accumulation of afferent input from sensory receptors during the period of cough suppression.

An alternative explanation could be that the sensitivity of the cough receptors in the airways is changed during suppression of cough. The central threshold for cough may be constant during cough suppression, but the receptor discharge may build up, either because they do not adapt during cough suppression, or because local conditions, such as mucus secretion, cause an increase in sensory nerve discharge. These properties would be consistent with what is known about airways receptors [10].

The results of this study demonstrate that cough due to upper respiratory tract infection can be suppressed. The voluntary suppression of cough may be a complicating factor in clinical trials on antitussive medications, and this could explain the great variability of cough as a symptom. In the present study, the population of subjects with cough fell into two distinct groups on the basis of cough suppression time, and this information may be of use in selecting a more homogeneous population of subjects when screening antitussive medications.

Acknowledgements: The authors would like to thank Procter and Gamble for sponsoring this project and H.W. Thomas for his help and advice on the statistical analysis of the data.

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