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Fifteen-Count Breathlessness Score: An Objective Measure for Children

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Summary. Breathlessness is an important symptom of respiratory disease and its quantification is useful, especially during exercise testing. However, measures of perceived breathlessness are not readily understood by children and are somewhat subjective. We studied an objective score: the 15-count breathlessness score, in which subjects take a deep breath and then count out loud to 15; the number of breaths taken to complete the count is the score. Fifty-four children with cystic fibrosis (CF) performed a standard 6-min walk and 3-min step test (30 steps/min for 3 min). The 15-count score was compared with the modified Borg scale after exercise. A further 45 children with CF and 33 healthy schoolchildren underwent an incremental step test (20, 30, and then 40 steps/min for 2 min each), using the 15-count score, then the Borg scale, and then a standard visual analogue score between increments.

The 15-count score was significantly increased after both the walk and the step test ($P < 0.0001$), although the step test made children significantly more breathless than the walk test ($P < 0.0001$). At baseline, there were no differences in any of the breathlessness scores between the CF and normal children. After the full 6 min of the incremental step test, CF children were significantly more breathless than the normal children, as measured by 15-count ($P < 0.0001$), Borg ($P < 0.0005$), and visual analogue scores ($P < 0.0005$). All scores increased significantly as exercise intensity increased over time, but the slope estimates were significantly greater for CF patients than for normal children ($P < 0.0005$).

The 15-count score has been evaluated as an objective measure of breathlessness. It is easy to explain and perform, and can be used by any child capable of counting fluently to 15 in any language. It is best used in conjunction with a subjective score, and either the Borg scale or a visual analogue score is appropriate. **Pediatr Pulmonol. 2000; 30:56–62.**

Key words: breathlessness; children; cystic fibrosis; exercise test score; dyspnea test score.

INTRODUCTION

Breathlessness is an important and often distressing symptom of children as well as adults with respiratory disease. It is defined as the subjective awareness of having difficulty breathing or feeling out of breath. Although usually synonymous, dyspnea tends to bring in the concept of discomfort or unpleasantness to the sensation of breathlessness. There are well-recognized means of measuring the subjective elements of breathlessness, such as the modified Borg scale of perceived breathlessness[1,2] or standard visual analogue scores.[3,4] In these, patients indicate how breathless they feel; these measures may be useful in the clinical situation, although some children find them difficult to understand. One of the problems is that the intensity of breathlessness does not necessarily reflect the degree of physiological alteration in cardiopulmonary function that can be measured.[5] An objective score would be useful to give an indication of how breathless the patient actually is, and this could be used as an outcome measure in exercise testing and clinical intervention trials.

The objective measure of breathlessness we studied has been variously named the *dyspnea index*, *ventilatory index*, and *ventilatory response index*. We have modified it slightly and renamed it the *15-count breathlessness*

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score. It has been used in cardiac and transplantation rehabilitation programs in adults and was developed by the Departments of Physical Therapy at Ranchos Los Amigos Medical Center, Downey, California, and the California State University at Fresno.[6] We wished to evaluate its use in children and compare it with more subjective measures of breathlessness. The score was studied during exercise testing in children with cystic fibrosis and in healthy children.

METHODS

The study consisted of two parts: 1) comparison of the 15-count score with the modified Borg scale in patients with CF undergoing the 3-min step test[7] and the 6-min walk,[8] and 2) comparison of the 15-count score with the modified Borg scale and visual analogue score in patients with CF and normal children undergoing an incremental step test. The study was approved by the Hospital Research Ethics Committee; parents and/or patients gave written informed consent.

Subjects

Subjects were children with CF attending our outpatient clinics or patients undergoing assessment for heart-lung transplantation. Exclusion criteria were: age under 6 years, a diagnosis of asthma (made on clinical grounds), current oxygen therapy, or resting oxygen saturation (SaO_2) less than 85%. Normal children over 6 years old were studied at local schools and a sports club.

Part 1

Fifty-four CF patients (32 girls and 22 boys) with a mean age of 12.5 years (range, 6–18 years) participated in this part of the study. Their mean baseline forced expiratory volume in 1 sec (FEV_1) was 61% of predicted values (range, 14–103%) for gender and height, while mean resting SaO_2 was 95% (range, 87–98%).

Part 2

Forty-five CF patients (26 girls and 19 boys) with a mean age of 13.1 years (range, 7–17 years) participated in this part of the study. Their mean baseline FEV_1 was 61% of predicted values (range, 24–103%), while their mean resting SaO_2 was 96% (range, 91–98%). There were 33 healthy children (20 girls, 13 boys) with a mean age of 12.6 years (range, 8–14 years) who performed the same tests.

Abbreviations	
CF	Cystic fibrosis
CI	Confidence interval
FEV_1	Forced expiratory volume in 1 sec
ns	Nonsignificant
SaO_2	Oxygen saturation

Breathlessness Scores

Fifteen-Count Breathlessness Score

The subject takes a deep breath and counts out loud to 15, taking about 8 sec to do so. The number of breaths needed to complete the count, including the initial breath, is the score (thus, the minimum score is one).

Modified Borg Scale

The Borg scale of perceived exertion[1] has been modified for measurement of breathlessness.[2] It has 12 points, 10 of which have accompanying verbal descriptors (see Appendix).

Visual Analogue Score

This consists of a 10-cm horizontal line with two anchor points, one at each extreme. On the left (zero) it is labelled, "I am not at all short of breath," while at the other end (10 cm) it is labelled, "The most short of breath I have ever been." Subjects puts a mark through the line where they think their breathlessness fits on this scale, which is then measured (in cm) from the zero point.

Exercise Tests

The 3-Min Step Test

Subjects stepped up and down a commercially available single step which is 15 cm (6 inches) high. The stepping rate of 30 per min for 3 min was controlled by a metronome. Patients could stop if they felt tired or if the SaO_2 fell below 75%, in which case the total number of steps up to that point was determined. Patients were shown how to change the leading leg to reduce localized muscle fatigue.

The 6-Min Walking Test

Subjects walked up and down a measured 17-m-long corridor for 6 min, accompanied by the investigator with the pulse oximeter on a trolley. The test is self-paced and subjects could rest when they wished, but the clock continued to run. The test was stopped if the SaO_2 fell below 75%.

The Incremental Step Test

This is a modification of the 3-min step test. The step is set at the same height, but subjects step at a rate of 20,

TABLE 1—Fifteen-Count Score and Modified Borg Scale for 54 CF Patients Before and After 3-Min Step Test and 6-Min Walk[1]

	15-count score			Borg scale		
	Pre	Post	P	Pre	Post	P
Step test	1.0 (1.0–1.0)	2.5 (2.0–3.0)	$P < 0.0001$	0.0 (0.0–0.0)	3.0 (0.5–4.0)	$P < 0.0001$
Walk	1.0 (1.0–1.3)	1.0 (1.0–2.0)	$P < 0.0001$	0.0 (0.0–0.1)	0.5 (0.0–2.0)	$P < 0.0001$
	P = ns	$P < 0.0001$		P = ns	$P < 0.0001$	

[1]Results are expressed as medians with interquartile ranges. ns, nonsignificant.

30, and then 40 steps per min for 2 min each, consecutively.

Study Design

Part 1

Baseline lung function was assessed by standard spirometry using a compact spirometer (Vitalograph, Buckingham, UK), and SaO_2 was measured using a Biox 3700e pulse oximeter (Ohmeda, Boulder, CO). The order in which subjects performed the exercise tests (3-min step test and 6-min walk) was randomized. The patients practiced both tests and then rested for 15 min. The first test was then performed, and the second test was started 30 min after the pulse rate and SaO_2 had returned to baseline pre-exercise levels. Standardized encouragement was offered during the tests, which were all supervised by the same investigator. Breathlessness was measured using the 15-count and Borg scores (in randomized order) before and immediately after exercise.

Twelve patients repeated the step test, and nine repeated the walk on consecutive days to assess repeatability.

Part 2

Baseline lung function and SaO_2 were measured in the CF patients as above. Subjects performed the incremental step test after baseline measurement of breathlessness, using all three breathlessness scores. The 15-count score was always performed first; the Borg and visual analogue scores were then completed in randomized order. After each 2 min of exercise, patients stopped so that breathlessness could be measured again before the stepping rate was increased. As measurement of all three scores took less than 30 sec to perform, the increments of exercise were almost continuous.

Statistical Analysis

Statistical analysis was performed using Minitab software (Minitab, Inc., State College, PA). Nonparametric Wilcoxon tests were used to compare the outcomes before and after exercise, and Mann-Whitney tests were used to compare different groups. Values of $P < 0.05$ were considered statistically significant. The rate of increase in breathlessness during the incremental step test was assessed using the slope estimates of the line that fit the data (with breathlessness scores regressed on time), and the group medians of these slopes were used to compare the different groups.[9] Reproducibility of the tests was assessed using Bland-Altman plots to compare results for the repeat tests.[10] The coefficient of repeatability was calculated using the British Standards Institution definition, i.e., twice the standard deviation of the differences.[10]

RESULTS

Part 1: 15-Count and Borg Scores in Patients With CF Undergoing the 3-Min Step Test and 6-Min Walk

Full details on the effects of both exercise tests on children with CF were published previously.[7] Briefly, heart rates increased significantly, while SaO_2 fell significantly during both exercise tests. Although the heart rates were significantly higher during the step test compared to the walk, the fall in SaO_2 was similar for both. Both the 15-count and Borg scores were significantly increased after the step test and walk, although the step test made the patients significantly more breathless than the walk, as measured by either score (Table 1).

There was a similar degree of correlation of the baseline FEV_1 with both the 15-count score ($r = 0.49$, $P <$ 0.0001) and the Borg score ($r = 0.47$, $P < 0.0001$) at the end of exercise.

The repeatability of the 15-count and Borg scores during duplicate step tests and 6-min walks was felt to be clinically acceptable although moderately better for the 15-count scores. Limits of agreement (mean ± 2 standard deviations)[10] for the 15-count score were −0.5 to 0.7 during the step test and −0.7 to 1.1 during the walk, while for the Borg score they were −1.5 to 1.5 during the step test and −1.1 to 1.9 during the walk. The coefficients of repeatability (as assessed by the Bland-Altman method)[10] for the absolute changes in 15-count scores were 0.58 for the step test and 0.94 for the walk, while for the Borg score they were 1.4 for the step test and 1.5 for the walk. This should, however, be put into the context of the small numbers used for this part of the study.

TABLE 2—Fifteen-Count Score, Modified Borg Scale, and Visual Analogue Score for 45 CF Patients and 33 Normal Children Before and After Incremental Step Test[1]

	15-count score			Borg scale			Visual analogue score		
	Pre	Post	*P*	Pre	Post	*P*	Pre	Post	*P*
CF	1.0 (1.0–1.0)	2.0 (2.0–3.0)	$P < 0.0001$	0.0 (0.0–0.5)	3.5 (3.0–5.0)	$P < 0.0001$	0.2 (0.0–0.8)	4.1 (2.4–6.2)	$P < 0.0001$
Normal	1.0 (1.0–1.0)	1.0 (1.0–2.0)	$P < 0.01$	0.0 (0.0–0.0)	2.0 (1.0–2.0)	$P < 0.0001$	0.0 (0.0–0.5)	2.0 (0.5–3.4)	$P < 0.0001$
	P = ns	$P < 0.0001$		P = ns	$P < 0.0005$		P = ns	$P < 0.0005$	

[1]Results are expressed as medians with interquartile ranges. ns, nonsignificant.

Part 2: 15-Count, Borg, and Visual Analogue Scores in Patients With CF and Normal Children Undergoing the Incremental Step Test

The heart rates (beats/min) rose significantly in both CF and normal children during exercise, with no difference between the two groups (mean (range), 101 (67–150), increasing to 151 (120–180), vs. 99 (65–137), increasing to 157 (116–190), respectively). The SaO_2 fell significantly ($P < 0.05$) more in the CF group than in the normal children: mean (95% CI) drop, 1.5% (0.9–2.1%) vs. 0.7% (0.2–1.2%).

At baseline, there were no differences in any of the breathlessness scores between CF and normal children, and after the full 6 min, all scores had increased significantly (Table 2, Figs. 1–3). However, in the normal children, the increase in 15-count score was less marked than that seen with the subjective Borg and visual analogue scores. As expected, the CF children were significantly more breathless after exercise than the normal children (both absolute values and change) as measured by all three scores (Table 2, Figs. 1–3). Changes in the Borg and visual analogue scores after exercise correlated well

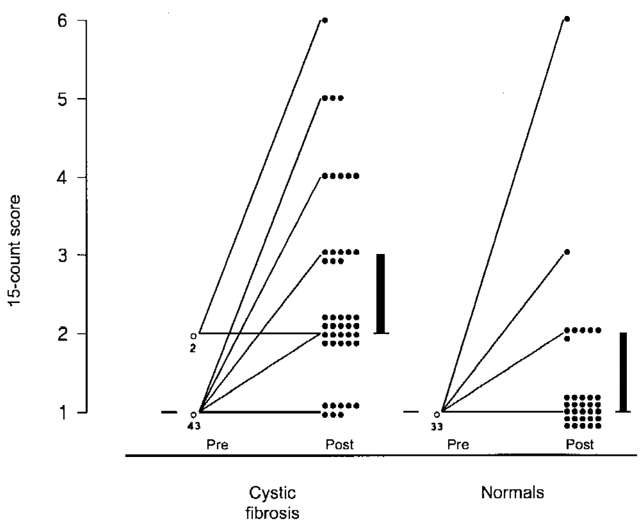

Fig. 1. Fifteen-count scores for 45 CF patients and 33 normal children before (open circles) and after (solid circles) incremental step test. Also shown are medians (lines) with interquartile ranges after (solid bars) exercise. Interquartile ranges before exercise are the same as the medians, hence are not shown.

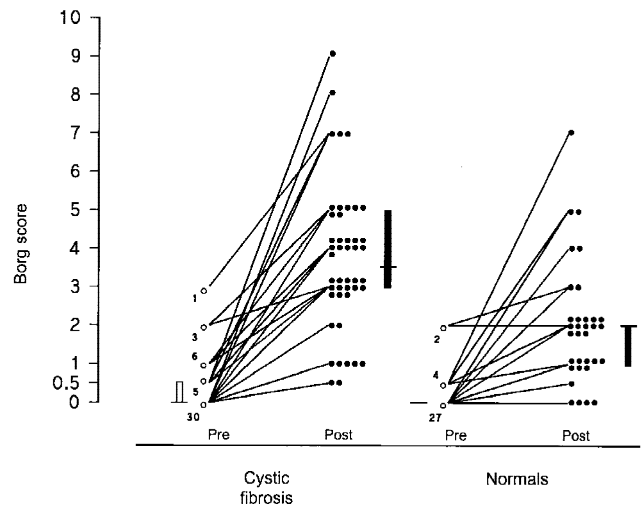

Fig. 2. Borg scores for 45 CF patients and 33 normal children before (open circles) and after (solid circles) incremental step test. Also shown are medians (lines) with interquartile ranges before (open bars) and after (solid bars) exercise. Interquartile range before exercise in the normal children is the same as the median, hence is not shown.

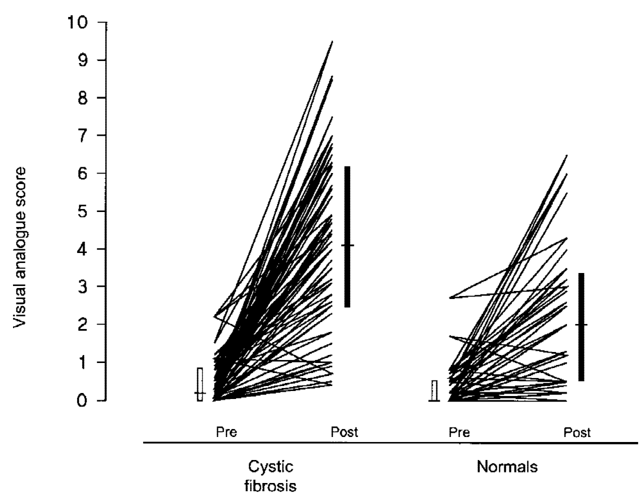

Fig. 3. Visual analogue scores for 45 CF patients and 33 normal children before (open circles) and after (solid circles) incremental step test. Also shown are medians (lines) with interquartile ranges before (open bars) and after (solid bars) exercise.

TABLE 3—Slope Estimates for 15-Count Score, Modified Borg Scale, and Visual Analogue Score for 45 CF Patients and 33 Normal Children for the Incremental Step Test.[1]

	15-count score	Borg scale	Visual analogue score
CF	0.20* (0.15–0.35)	0.53* (0.34–0.69)	0.57* (0.25–0.98)
Normal	0.00** (0.00–0.15)	0.28* (0.13–0.34)	0.27* (0.07–0.47)
	$P < 0.0001$	$P < 0.0005$	$P < 0.0005$

[1]Breathlessness scores for each subject are regressed on time, i.e., scores at 0, 2, 4, and 6 min of exercise. Group results are expressed as medians of the slopes with interquartile ranges. Slope estimates are all significant when compared to zero.
*$P < 0.0001$, **$P < 0.01$.

with each other in both CF (r = 0.63, $P < 0.0001$) and normal children (r = 0.77, $P < 0.0001$), whereas the 15-count score correlated poorly with the other two scores.

In the two groups, the mean slope estimates were all positive and significant for the three scores (Table 3). This suggests that all scores increased in an incremental fashion as the work rate (stepping rate) increased and patients became more breathless. The slopes were significantly greater for the CF children compared to normal children (Table 3).

DISCUSSION

Breathlessness is a common symptom in patients with respiratory disease, and it has a large impact on functional disability. Although it can affect the daily routines and activities of children as well as adults,[11] it is a symptom which is often overlooked in pediatric practice. This study evaluated methods of measuring breathlessness and has demonstrated that the 15-count score could differentiate degrees of breathlessness induced by exercise of varying intensity in children with cystic fibrosis. It could also discriminate between healthy children and children with cystic fibrosis in terms of their exercise-induced breathlessness. This scoring system has been known by several names, some of which have also been applied to other physiological measures (e.g., dyspnea index is more commonly defined as the ratio of min ventilation to maximal voluntary ventilation), and so we have renamed it the *15-count breathlessness score* to avoid confusion.

We found this score to be a simple and useful objective measure of breathlessness which was easily applicable to children. It can be used by anyone old enough to count fluently to 15 and can be used in whatever language the child speaks. No equipment is needed and it can easily be performed in a ward, in a clinic, in the exercise laboratory, or on field studies. It is, however, necessary to control certain variables when using the score. The speed of counting is important, as a subject counting more quickly is likely to take fewer breaths (and hence obtain a lower score) than someone counting more slowly. A consistent speed of counting is particularly critical if a subject is repeating scores after exercise or a therapeutic intervention. The investigators demonstrated how fast to count in order to complete it in 8 sec. The children copied and practiced this when learning how to perform the exercise tests. In practice, it was easy to both demonstrate and learn the speed of counting which was then found to be quite consistent. A metronome is not recommended, as it would confuse children who take extra breaths since they would then get out of synchrony with the metronome's beat. Another important variable to control is how deep a breath the subject takes at the start of the count, as a low starting lung volume will make it harder to reach 15 without taking further breaths. Subjects were told to take a deep breath, which was essentially to vital capacity. Although this could not be measured, investigators could tell when the subject had not breathed in fully. Minor differences in speed of counting or starting lung volumes would not have accounted for the differences in the 15-count score produced after exercise in this study.

Important reasons for measuring breathlessness include differentiating between people with varying degrees of breathlessness (discrimination) and determining how much breathlessness has changed over time (evaluation).[12] Clinical nonexercise ratings of breathlessness, using either a questionnaire or direct interview, can be readily obtained from a symptomatic adult,[13] but these measures are less applicable to children. With mild disease, breathlessness may only occur during exercise and may be missed if the child were only studied at rest. Exercise testing is a valuable tool in assessing children with known respiratory disease,[14] and the methods available for studying children with CF were recently reviewed.[15] Measuring a change in breathlessness during an exercise test is a good outcome measure if it can be quantified reliably. The measurement needs to be responsive (reflecting the ability to detect change) and have construct validity (the measured change in breathlessness should correlate with other expected physiological changes).[12] In this study, the 15-count score has certainly been shown to be responsive, with marked and significant differences found in the score after exercise of differing intensity. Changes in the 15-count score are, however, more noticeable during more strenuous exercise (3-min step test vs. 6-min walk) and also in the subjects with underlying pulmonary disease. Although we found statistically significant differences in the 15-count score in the normal children after 6 min of stepping, for the majority of subjects (25/33) there was no change in the objective score (Fig. 1). Interestingly, however, these healthy children still scored themselves as markedly more breathless after exercise using the subjective scores. For this reason, the 15-count score is best used in those prone to breathlessness, or in healthy subjects undergoing more severe exercise than was used in this study. Using a cutoff score of 2, the 15-count score was found to be useful as a discriminating tool in 17/45 (38%) CF children compared to only 2/33 (6%) normal children obtaining a score greater than 2 after exercise. Construct validity has also been demonstrated for this scoring method, as an increase in the 15-count breathlessness score was accompanied by an appropriate increase in measured heart rate in all subjects and a fall in oxygen saturation in those with CF. Reliability of the 15-count score has been further demonstrated by the consistently positive and significant slope estimates found during the increments of exercise intensity and the acceptable measures of repeatability.

When using the subjective measures, it was important to ensure that the children understood the term breathlessness, so they were asked to define it. Some examples of the definitions given by the children with CF after they completed the exercise tests were: "tired; tight; hard; wheezy; hot; can't speak properly; sucking air out of me; something stuck down my throat; someone standing on your chest; someone trying to suffocate you; like an elephant is sitting on your chest; being underwater and difficult to get air after you come up; pain in the chest; feels like you're going to die." The wide range of descriptors used by the children illustrates why more objective measures such as the 15-count score are useful additions to the traditional subjective scoring methods. Adults also use a large number of phrases to describe their own sensations of breathlessness, and studies have been conducted to test the validity of using these various descriptors,[11,16,17] although this is unlikely to be useful in young children.

There are several established methods for subjectively quantifying breathlessness induced by exercise. The modified Borg scale[1,2] and visual analogue score[3,4] are the main instruments used. In general, similar scores are obtained by both methods,[18] which has been confirmed in this study. It is interesting that the two methods give such similar scores, as there is an in-built bias to score under 5 with the Borg scale, since 5 represents "severe" breathlessness, which is usually as high as patients wish to score themselves. It is said that the accompanying descriptors in the Borg score enable direct comparisons among individuals because a specific rating represents the same intensity of breathlessness.[12] In addition, the verbal descriptors are placed so that a doubling of the numerical score corresponds to a twofold increase in sensation intensity.[19] The Borg scale has been shown to be closely correlated with the post-exercise level of ventilation in adults with cystic fibrosis.[20] In practice, use of this scale is problematic in many children, due to their difficulties in understanding some of the terms (such as moderate or maximal). We suspect that many children simply use the number ratings 1–10 and ignore the descriptors, so that the Borg scale is often used in a similar way to the visual analogue score. A theoretical advantage of the latter is that it is a continuous variable which is supposed to be easier to use than scoring with discrete numbers. A problem with the visual analogue score is that the anchor points ("I am not at all short of breath" or "The most short of breath I have ever been") are specific to the individual, making comparisons of scores between different people less reliable. A score of 5 for one child may be very different from what another child considers 5 to represent. Children often score themselves in the middle of the line as halfway represents an average day for them, i.e., "I am as breathless as I usually feel after exercise," which of course may be very different for different individuals. Other methods tried in children include a four-point descriptor scale and a color shade scale,[11] but these are not sensitive enough when it comes to monitoring change over a short time.

The problems with the Borg and visual analogue scores highlight the difficulties of measuring a subjective feeling or symptom. However, it does not invalidate their use, as it is important to know how breathless children feel or think they feel, since this is the symptom that is causing them concern. Just as in quantifying pain, what patients say they are experiencing is not always in keeping with their appearance to others (parents and medical attendants). It is for this reason that the 15-count score is a useful adjunct, as it is designed to give a more objective and reproducible measure of breathlessness. Its use should also make comparisons between individuals and within the same individual at different time points more valid. The 15-count score will not take into account the intensity of the "unpleasantness" of breathlessness, which is something only the patient can know, and which is why our score is best used in conjunction with one of the subjective scores.

APPENDIX—Modified Borg Scale

0	Nothing at all
0.5	Very very slight (just noticeable)
1	Very slight
2	Slight
3	Moderate
4	Somewhat severe
5	Severe
6	
7	Very severe
8	
9	Very very severe (almost maximal)
10	Maximal

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